Millimeter-wave spectrometer for chirality and relative abundance determination of amino acid biomarkers

Completed Technology Project (2017 - 2020)

Project Introduction

The search for life is a high-priority science objective in the 2013 Decadal Survey paper Vision and Voyages for Planetary Science in the Decade 2013–2022. The paper recommends (page 240) "a detailed characterization of organics to search for signatures of biological origin, such as molecules with a preferred chirality or unusual patterns of molecular weights" as a key future investigation for determining the possibility of life beyond Earth. While mass spectrometry has often been proposed for measuring the abundance patterns of molecular weights, it lacks the chirality detection capability required for chiral analyses of chiral molecules such as amino acids, and cannot uniquely identify specific structure-based isomers such as fatty acids. Current chirality detection technologies all involve complicated sample isolation and/or chemical derivatization processes. The novel millimeter-wave chirality detection spectrometer (ChiralSpec) advances key technologies to enable chirality detection and discrimination of structural isomers with a simple instrument. ChiralSpec is applicable to mission focus areas such as Enceladus, Europa, Titan, and Mars. It could be used on planetary in-situ probes to measure amino acids, fatty acids, and other organic molecules in the gas phase or brought into the gas phase. Two of the unique advantages of ChiralSpec are (1) it can analyze the mixture of gases without separating them first; and (2) it has an extraordinary capability for distinguishing isomers. ChiralSpec employs an innovative microwave three-wave mixing technology for chirality detection and the cavity resonance technology for sensitivity enhancement. ChiralSpec can be operated under two modes: (1) survey mode, with the instrument acting as a traditional microwave spectrometer to characterize chemical composition and quantify abundance of planetary samples; and (2) chirality detection mode, with the instrument determining which enantiomer is in excess and how much it is in excess for each existing chiral molecule. ChiralSpec contains two parts: a polarized pulsing transmitter and receiver system, and a three-axis resonator chamber. We will design ChiralSpec covering the 75–215 GHz region and perform chirality experiments first with a volatile chiral molecule propylene oxide at room temperature, and then with an nonvolatile amino acid—alanine—at 77 K. Our implementation develops and demonstrates ChiralSpec measurement technologies in the millimeter-wave region: (1) Design and fabricate the polarized pulsing transmitter and receiver system (2) Design and fabricate the three-axis resonator chamber (3) Integrate the pulsing system and the resonator chamber (4) Perform laboratory chirality experiments to demonstrate ChiralSpec's sensitivity. ChiralSpec has entry TRL2 and exit TRL3. The period of performance is 3 years with a start in CY2017.

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Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations

Millimeter-wave spectrometer for chirality and relative abundance determination of amino acid biomarkers

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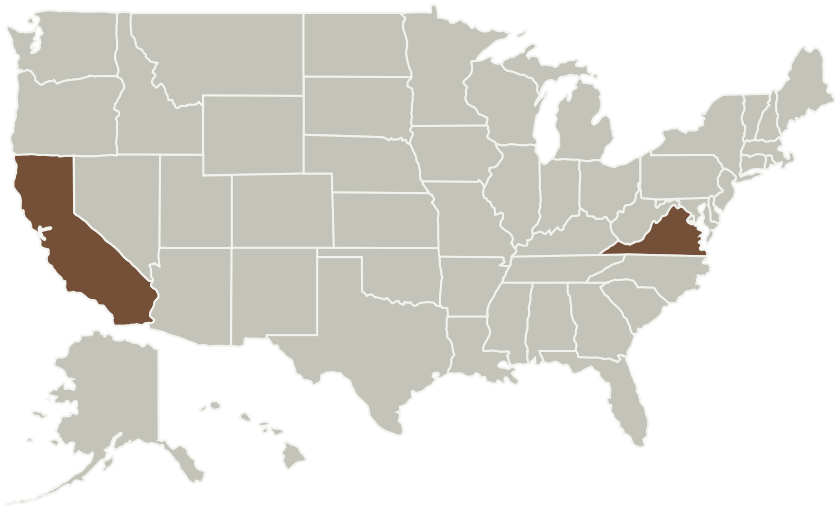
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
California Institute of Technology(CalTech)	Supporting Organization	Academia	Pasadena, California

Primary U.S. Work Locations	
California	Virginia

Project Management

Program Director:
Carolyn R Mercer

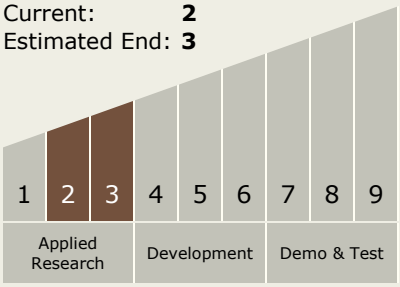
Program Manager:
Haris Riris

Principal Investigator:
Shanshan Yu

Co-Investigators:
Michael J Malaska
Theodore J Reck
Brooks H Pate
Robert P Hodyss
Karen R Piggee
John C Pearson

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.3 In-Situ Instruments and Sensors

Continued on following page.

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Technology Areas *(cont.)*

- TX08.3.4 Environment Sensors

Target Destination

Others Inside the Solar System